

REMARKS

The present application was filed on April 14, 2000 with claims 1 through 30. Claims 1 through 30 are presently pending in the above-identified patent application. Claims 1, 4, 10, 12, 14, 15, 16, and 27-30 are proposed to be amended herein.

5 In the Office Action, the drawings, abstract, and specification have been objected to due to indicated informalities. The Examiner rejected claims 1-30 under 35 U.S.C. §112, first paragraph, as containing subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention. The Examiner
10 rejected claims 4, 10-12, and 15-16 under 35 U.S.C. §112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as the invention. The Examiner also rejected claims 1, 13-14, and 26-30 under 35 U.S.C. §102(a) as being anticipated by Crossno et al., "Spiraling Edge: Fast Surface Reconstruction from Partially Organized Sample Points," Proceedings
15 of Visualization '99, October 1999, pages 317-324, and rejected claims 5, 7, 18, and 20 under 35 U.S.C. §103(a) as being unpatentable over Crossno et al., and further in view of Pulli et al., "Robust Meshes from Multiple Range Maps," Proceedings of International Conference on Recent Advances in 3-D Digital Imaging and Modeling, May 1997, pages 205-211. The Examiner indicated that claims 2-4, 6, 8-12, 15-17, 19, and 21-25 would
20 be allowable if rewritten in independent form including all of the limitations of the base claims and any intervening claims.

The present invention is directed to a method and apparatus for finding a triangle mesh that interpolates a set of points obtained from a scanning system. A ball-pivoting algorithm computes a triangle mesh interpolating a given point cloud. The
25 disclosed ball-pivoting algorithm triangulates a set of points by "rolling" a ball of radius r on the point cloud. The points are surface samples acquired with multiple range scans of an object. The ball-pivoting algorithm starts with a seed triangle, and pivots the ball of a given radius, r , around an edge of the triangle. During the pivoting operation, the ball revolves around the edge while keeping in contact with the edge's endpoints. The ball
30 pivots until it touches another scan point, forming another triangle. The ball-pivoting operation continues until all reachable edges have been tried, and then starts from another

seed triangle, until all scan points have been considered. The ball-pivoting algorithm is related to alpha-shapes, and given sufficiently dense sampling, it reconstructs a surface homeomorphic to and within a bounded distance from the original manifold.

Formal Objections

5 The drawings were objected to due to incorrect margins and numbers and reference characters that are not plain and legible.

Applicants are submitting formal drawings herewith and respectfully request that this objection be withdrawn.

The Abstract has been objected to because it exceeds 150 words in length.

10 The Abstract has been amended to be 150 words or less in length and Applicants respectfully request that the objection to the Abstract be withdrawn.

 The specification was objected to because “a memory subsystem 110” (page 8, line 8) should be “a memory subsystem 114,” “a system bus 112” (page 8, lines 9-10) should be “a system bus 116,” “from P1 to PK-1” (page 19, line 22) should be
15 “from PI to PK-1,” and “vertex 920” (page 20, line 19) should be “edge 920.” The Examiner also noted that a section entitled “Multiple Passes” (page 14, line 13, and page 15, line 19) cannot be found in the specification.

 The specification has been amended to correct the cited typographical errors and Applicants respectfully request that the objection to the specification be
20 withdrawn.

 The Examiner asserts that the incorporation of essential material into the application by reference to Bernardini et al. (page 12, lines 13-16) is improper because it is not a U.S. patent, U.S. patent application publication, or a pending U.S. application. The Examiner also requests a copy of the cited reference (Bernardini et al.).

25 Applicants note that the reference cited by the Examiner is *not* essential material for enabling the present invention. Thus, Applicants respectfully request that the objection to the cited “incorporated by reference” statements be withdrawn. Applicants also submit an IDS with a copy of the cited reference herewith.

Section 112 Rejections

Claims 1-30 were rejected under 35 U.S.C. §112, first paragraph, as containing subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly
5 connected, to make and/or use the invention. Regarding claims 1, 27, and 29, the Examiner asserts that, without undue experimentation, it is unclear for one skilled in the art whether the surface of an object will be reconstructed without also repeating the “finding a seed triangle” step. Claims 1, 27, and 29 have been amended in accordance with the Examiner’s suggestion in an effort to clarify this issue. Regarding claims 14, 28,
10 and 30, the Examiner asserts that, unless the two contact points on the active-edge front of said mesh are adjacent, “said two contact points forming an edge” will form a new edge and divide the active-edge front, and, therefore, without undue experimentation, it is unclear for one skilled in the art how to reconstruct the surface by pivoting the ball as claimed. Claims 14, 28, and 30 have been amended in accordance with the Examiner’s
15 suggestion in an effort to clarify this issue.

Applicants respectfully request that the rejection under 35 U.S.C. §112, first paragraph, be withdrawn.

Claims 4, 10-12, and 15-16 were rejected under 35 U.S.C. §112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the
20 subject matter which Applicant regards as the invention. Regarding claim 4, the Examiner asserts that there is insufficient antecedent basis for the limitation “the point set.” Regarding claim 10, the Examiner asserts that there is insufficient antecedent basis for the limitation “the same voxel.” Regarding claim 12, the Examiner asserts that there is insufficient antecedent basis for the limitation “the previous and next edge.”
25 Regarding claims 15 and 16, the Examiner asserts that there is insufficient antecedent basis for the limitation “step of finding three initial points.”

Claims 4, 10-12, and 15-16 have been amended to correct the antecedent basis of the cited terms and Applicants respectfully request that the section 112 rejections be withdrawn.

Independent Claims 1, 14 and 27-30

Independent claims 1, 14, and 27-30 were rejected under 35 U.S.C. §102(a) as being anticipated by Crossno et al. Regarding claim 1, the Examiner asserts that Crossno discloses pivoting a ball around an edge of said triangulated mesh until a
 5 new point in said scan data is hit by said ball, wherein said edge and said new point define a new triangle; adding said new triangle to said triangulated mesh (traversing the edge ring, page 319, left column, section 5; Figure 2).

Applicants note that, while Crossno does disclose incrementally expanding a triangulated region by adding more triangles along its front, the steps
 10 involved in the reconstruction are fundamentally different from the present invention. Crossno assumes that the neighbors of each point in the set have been *precomputed by a separate algorithm*. Crossno also requires that the set of neighbors to a given point be sorted by angle around its normal, under the assumption that the points lay close to a plane. This is *not* the same as *pivoting a ball* of fixed radius around an edge of a
 15 triangulated region front (or "edge"). The ball pivoting method finds a point in the vicinity of the front and, by construction, an empty ball that touches three points, forming a unique, new triangle. This eliminates the need for the series of special cases and ad-hoc geometric tests required by Crossno. Independent claims 1, 27, and 29 require *pivoting a ball* around an edge of said triangulated mesh until a new point in said scan data is hit by
 20 said ball, wherein said edge and said new point define a new triangle and adding said new triangle to said triangulated mesh. Independent claims 14, 28, and 30 require keeping said ball in contact with two points on the active-edge front of said mesh and *pivoting said ball* until it touches another point in said scan data, said two contact points forming an edge; forming a new triangle with said triplet of points contacted by said ball; and
 25 adding said new triangle to said mesh.

Thus, Crossno does not disclose or suggest pivoting a ball around an edge of said triangulated mesh until a new point in said scan data is hit by said ball, wherein said edge and said new point define a new triangle and adding said new triangle to said triangulated mesh, as required by independent claims 1, 27, and 29, and does not disclose
 30 or suggest keeping said ball in contact with two points on the active-edge front of said mesh and pivoting said ball until it touches another point in said scan data, said two

contact points forming an edge; forming a new triangle with said triplet of points contacted by said ball; and adding said new triangle to said mesh, as required by independent claims 14, 28, and 30.

Additional Cited References

5 Pulli et al. was also cited by the Examiner for its disclosure of a method for modeling the surface of an object from a sequence of range maps. Applicants acknowledge that Pulli builds a surface representation from a set of sample points. Pulli, however, assumes that the input data comes organized in a set of range maps. Pulli uses the range maps to classify cubic cells of a 3-dimensional grid over-imposed on the
10 sample points into internal and external cells which lie partially inside are divided into eight smaller cells, and the process is reapplied to the smaller cells, until a preset maximum level of subdivision is reached. At the end of this process, the boundary faces between inside or boundary cubes and outside cubes, at the finest level of subdivision, are divided into two triangles and collected into the final triangulated surface representation.
15 The extracted surface therefore does not pass through the original sample points, but only approximates their position.

Thus, Pulli does not disclose or suggest pivoting a ball around an edge of said triangulated mesh until a new point in said scan data is hit by said ball, wherein said edge and said new point define a new triangle and adding said new triangle to said
20 triangulated mesh, as required by independent claims 1, 27, and 29, and does not disclose or suggest keeping said ball in contact with two points on the active-edge front of said mesh and pivoting said ball until it touches another point in said scan data, said two contact points forming an edge; forming a new triangle with said triplet of points contacted by said ball; and adding said new triangle to said mesh, as required by
25 independent claims 14, 28, and 30.

Dependent Claims 2-13 and 15-26

Dependent claims 13 and 26 were rejected under 35 U.S.C. §102(a) as being anticipated by Crossno et al. and claims 5, 7, 18, and 20 were rejected under 35 U.S.C. §103(a) as being unpatentable over Crossno et al., and further in view of Pulli et
30 al.

Claims 2-13 and 15-26 are dependent on claims 1 and 14, respectively, and are therefore patentably distinguished over Crossno et al. and Pulli et al. (alone or in any combination) because of their dependency from independent claims 1 and 14 for the reasons set forth above, as well as other elements these claims add in combination to their base claim. The Examiner has already indicated that claims 2-4, 6, 8-12, 15-17, 19, and 21-25 would be allowable if rewritten in independent form including all of the limitations of the base claims and any intervening claims.

All of the pending claims, i.e., claims 1-30, are in condition for allowance and such favorable action is earnestly solicited.

If any outstanding issues remain, or if the Examiner has any further suggestions for expediting allowance of this application, the Examiner is invited to contact the undersigned at the telephone number indicated below.

The Examiner's attention to this matter is appreciated.

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Respectfully submitted,



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Kevin M. Mason
Attorney for Applicants
Reg. No. 36,597
Ryan, Mason & Lewis, LLP
1300 Post Road, Suite 205
Fairfield, CT 06824
(203) 255-6560